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Striped bass culture in eastern Canada

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ABSTRACT

Striped bass (*Morone saxatilis*) culture in eastern Canada began with experimental enhancement and rearing programs in the 1980s. Nineteen facilities have cultured striped bass in the region, but only 11 of these continue to work with the species. Eight small commercial aquaculture ventures have been initiated in southwestern New Brunswick, mainland Nova Scotia, Cape Breton Island, Prince Edward Island, and eastern Quebec. Four of these operations have ceased bass culture, and the remaining four raise bass at a small scale with limited commercial sales. The St. Andrews Biological Station has ended its striped bass program, but research and development work continues at the Huntsman Marine Sciences Centre and the Nova Scotia Agricultural College. Pilot culture projects also continue at divested federal hatcheries in Cardigan PEI and Miramichi NB. To date, major capital investment, appropriate sites and equipment, and expert husbandry have not been brought together in a single striped bass venture in eastern Canada. Reliable information on striped bass transfers and escapes is necessary for development of strains suitable for aquaculture, to evaluate potential alteration of the genetic make-up of wild stocks through interbreeding of escapees and wild fish, and to trace potential routes of disease transmission. It is recommended that a system be established to record and archive such information for eastern Canada.

RESUMÉ

La culture du bar rayé (Morone saxitilis) à l'est du Canada a commencé avec des programmes d'ensemensement et d'élevage dans les années 1980. Dix-neuf installations ont pratiqué l'élevage du bar rayé dans la région, dont seulement onze continuent de travailler avec l'espèce. Huit projets d'aquaculture ont été mis sur pied dans le sud-ouest du Nouveau-Brunswick, la terre ferme de la Nouvelle-Écosse, l'île du Cap Breton, l'île du Prince Édouard, et l'est du Québec. Quatre de ceux-ci ont cessé la culture du bar rayé, tandis que les quatre autres continuent d'élever le bar à petite échelle et connaissant des ventes limitées. La Station biologique de St. Andrews a terminé son programme sur bar rayé, mais les travaux de recherche et de développement continuent au Centre des sciences de la mer Huntsman et au Collège d'Agriculture de la Nouvelle-Écosse. Des projets pilots continuent aussi aux écloseries de Cardigan à l'IPÉ, et celui de la Miramichi au N-B, qui appartenaient auparavant au gouvernement fédéral. Jusqu'à date, des investissements majeurs en capitaux, les sites et les équipements appropriés, ainsi que l'expertise en élevage n'ont pas tous été rassemblés dans un seul projet d'élevage de bar rayé à l'est du Canada. De l'information fiable sur les transfères et les évasions est nécessaire pour le développement de races propices à l'aquaculture, pour une évaluation des changements potentiels dans le génome des bars sauvages dus aux croisements entre ceux-ci et les bars évadés, et pour tracer les routes que peuvent prendre les maladies. L'établissement d'un système pour enregistrer et pour mettre en archives de telles informations pour l'est du Canada est recommandé.

INTRODUCTION

The striped bass (*Morone saxatilis*) presently exists in only two confirmed spawning populations in eastern Canada; one in the southern Gulf of St. Lawrence (Miramichi River) and one in the Bay of Fundy system (the Shubenacadie River and its tributary, the Stewiacke). However, striped bass are commonly encountered in a wide geographic area of the Maritime Provinces due to the species' highly mobile lifestyle (Bradford et al. 1999a, 1999b). The commercial fishery for striped bass has been discontinued because of the small size of remaining stocks, but Canadian interest in striped bass aquaculture has recently intensified, following the development of a significant US industry (Harrell 1999). In addition, striped bass are considered an attractive sport fish, and hatchery stocking programs may have potential in re-establishing spawning populations in areas from which they have been extirpated, or in enhancing populations in areas where they naturally occur.

The genetic lineage of cultured fish is important both to the culturist and to the conservationist. Comparative growth trials of striped bass raised in standardized conditions have revealed a latitudinal cline in innate growth rates, with northern fish outgrowing those from southern regions (Conover et al. 1997, Brown et al. 1998, D. Conover pers. comm.; see Appendix 1 for affiliations of personal communicants). This suggests that Canadian fish, especially those from the northern range limit (the Miramichi), might be particularly suitable for aquaculture operations. In many aquaculture settings, there is a possibility of fish escaping, which may lead to the introduction of cultured genotypes into the gene pool of local wild fish.

Since the beginning of Canadian striped bass culture in the early 1980s, culture has been attempted at numerous sites in the three Maritime Provinces and Quebec. This report 1) documents the history and present status of striped bass culture operations in eastern Canada, 2) tracks the genetic lineage of transferred fish where possible, and 3) outlines information requirements for the management of striped bass culture in the context of wild striped bass conservation.

STRIPED BASS CULTURE IN EASTERN CANADA

Rearing practices

The following account of striped bass rearing methods is summarized from Peterson et al. (1996). Striped bass collected for broodstock can be maintained on a diet of pelleted fish food, although fish which are stressed on capture may be reluctant to take artificial food. Ovarian development is monitored by removing eggs through a catheter. Spawning is induced by hormone injection when the eggs reach 0.8 - 1.0 mm in diameter. Eggs are released by the female and milt is released by the male without stripping. The fertilized eggs are moved to other

containers where they hatch in 48-72 hours at 16-18°C. At 5-10 days post-hatch the yolk sac is depleted and the larvae are fed *Artemia* nauplii. An alternative to *Artemia* feeding is pond rearing, in which larvae are placed in open ponds where they forage on zooplancton, particularly rotifers. Striped bass in the juvenile stage can be fed artificial fish food, using the same pellet size as recommended for juvenile salmon of similar size. Young striped bass can be raised for grow-out either in tanks, earthen ponds, or in sea cages; all three methods have been used in eastern Canada. Salt or brackish water gives superior growth rates to fresh water. Striped bass are warm-water fish, and warm temperatures (≥15°C) are necessary for rapid growth.

Site accounts

This section gives accounts of all the striped bass culture operations in eastern Canada known to the authors. The information comes chiefly from present and former facility operators via written reports and (more frequently) telephone interviews. In most cases site histories, including origins and fates of fish, were supplied from memory. Hence there is much unevenness in the level of detail provided. In some cases of fish transfers among sites, operators of the providing and receiving sites provided reports which differed in date, fish origin, or other particulars. These discrepancies have been resolved to the extent possible by further discussions with facility operators, but it is possible that errors remain.

St. Andrews Biological Station

The St. Andrews Biological Station (SABS) is a Department of Fisheries and Oceans research station in southwestern New Brunswick (Fig. 1). Experimental striped bass culture was initiated in 1988 as part of a program to investigate the suitability of several species as aquaculture candidates. Five spawners (three females, two males) were collected from the Stewiacke River, NS (Fig. 1), in early June 1988. They were maintained at SABS until the spring of 1997, and were spawned annually from 1990. In July 1989 an additional five broodfish (four females, one male) were obtained from the fish collection facility at Mactaquac on the Saint John River. At the same time, a male bass was obtained from the adult salmon trap operated by the Atlantic Salmon Federation in Chamcook NB. The Saint John and Chamcook fish are of presumed US origin (Bradford et al. 1999a). These fish were also spawned regularly from 1991 onward.

Egg and larval quality from annual spawnings was usually excellent. The progeny were used for experimental purposes at SABS and for supply to other researchers and prospective striped bass culture facilities. Eggs and larvae were supplied to Huntsman Marine Science Centre, Maritime Culture Systems (St. Martins, NB), Two Rivers Bass Hatchery (Stewiacke, NS), and the State University of New York at Stony Brook (SUNY). The Stewiacke fish sent to SUNY, and Miramichi fish subsequently sent to the same location, were used for investigations of latitudinal variation in intrinsic growth rate (Conover et al. 1997, D. Conover pers. comm.).

In 1991, several hundred juvenile striped bass were obtained from eel fishermen in Richibucto, NB. Most were used in osmoregulation studies, but six were kept as prospective broodstock, and reached maturity in 1996. These fish were maintained in a common tank with four fish collected as juveniles from the Kouchibouguac River, NB, by Bill Hogan of Huntsman. They were spawned together as "Miramichi" stock.

Several thousand 5-10 g juveniles were given to Connors Bros. and to Earl Carpenter in the early 1990s for culture at Lake Utopia and Tobique, respectively. However, temperature and water hardness were unsuitable at these facilities and the bass did not grow well, and were destroyed. Several dozen larger juveniles were placed in a sea cage with several thousand Atlantic salmon in Beaver Harbour. Although they overwintered successfully, they showed poor growth, and were destroyed.

In 1994, several hundred juvenile bass of Stewiacke/Shubenacadie origin were sent to Whycocomagh, Cape Breton Island (Loch Bras d'Or Salmon Farms). Aquafutures, a culture facility in Massachusetts, acquired several hundred juveniles of both Miramichi and Stewiacke/Shubenacadie origin for their genetics program. The last 200 juveniles reared at SABS (Miramichi stock) were given to the Shippagan Marine Centre in fall 1997, and were subsequently acquired by the Quebec Aquarium and by the Montreal Biodome. The SABS striped bass program was discontinued in 1997. The Saint John and Miramichi broodfish were given to Huntsman, and the Stewiacke/Shubenacadie fish were destroyed.

Huntsman Marine Science Centre

The Huntsman Marine Science Centre, in St. Andrews NB (Fig. 1), is operated by a consortium of eastern Canadian universities. Huntsman's striped bass program has concentrated on the production of eggs and juveniles for distribution to private industry. Basic research on culture techniques has been completed within the confines of this production. A chronology of striped bass work follows.

In 1989-1990, wild-caught bass from the Miramichi, Richibucto, and Kouchibouguac Rivers were held at Huntsman. Nine hundred fish from these rivers were used in experiments on the effects of temperature and salinity on growth. All of these fish were eventually transferred to Maritime Culture Systems, St. Martins.

In 1991-1992, 40 juvenile striped bass were collected from the Kouchibouguac River and transferred to Huntsman for broodstock development.

In 1993-1994, broodstock of Stewiacke River origin were spawned at SABS and eggs were transferred to Huntsman. Five thousand juveniles were produced. Research on the effect of stocking density on growth and food conversion was completed. Seven large broodstock of Saint John origin were transferred from SABS to Huntsman.

In 1995, bass which had hatched in 1993 and 1994 were stocked at the Eldridge grow-out facility near St. Andrews. The aim of the project was to assess the suitability of culture of striped bass in a euryhaline pond environment. Growth rates of stocked fish were excellent but there were disease and culture system problems which limited the success of the experiment.

In 1996-1997, 30,000 juveniles (Saint John River origin) were reared to a mean weight of 5 g and transferred to Hooper's Hatchery. Growth rates of stocked fish were good but problems with the culture system compromised the project's overall success.

In 1998 about 200,000 eggs from Saint John origin broodstock were transferred from Huntsman to the Nova Scotia Agricultural College in Truro. An additional 100,000-150,000 eggs were transferred to Hooper's Hatchery.

Huntsman currently holds seven (10-18 kg) striped bass of Saint John origin and six (2-3 kg) striped bass of Kouchibouguac/Miramichi origin. Plans are for provision of eggs to interested private industry hatcheries. Production of juveniles and intensive research projects are not anticipated.

Woodstock Cold Storage, Bayside NB

A fish culture facility has been set up to take advantage of waste heat generated by the refrigeration units at this large shipping terminal in southwest NB. Water piped from Chamcook Lake is warmed by the coolant waters of the refrigeration compressors via heat exchangers. Fish are held in outdoor tanks. In fall 1997, young-of-the-year striped bass were obtained from Huntsman for pilot growth trials. Blasting at a nearby quarry has stressed the fish and survivorship has been poor. The operators of the facility do not anticipate intensive work on striped bass until blasting operations move further from the site.

Hooper's Hatchery, St. George NB

This is a private facility at Mascarene, adjacent to St. George in southwestern New Brunswick (Fig. 1). It consists of several aquaria and raceway tanks, housed indoors. Water for these tanks can be pumped from a nearby spring-fed lake (Lelands Lake), or from the estuary of the Magaguadavic River. Effluent water drains into the Magaguadavic estuary.

No spawning has taken place at this facility, and all culture operations are based on eggs and larvae supplied by Huntsman. Following small-scale culture trials in 1995 and 1996, Hooper's Hatchery received the products of the spawning of one pair of bass in each of 1997 and 1998. These fish were of Saint John River origin. In 1997, post-hatch larvae were sold to two US aquaculture operators. Aquafutures of Massachusetts successfully raised these larvae, but Sea Chick of Mississippi encountered difficulties with the larvae and all died. Larvae not sold to these firms were retained at Hooper's Hatchery. In January 1998, an intense ice storm caused widespread power interruptions. Following the failure of a backup generator, the striped bass were transferred to salt water tanks at nearby Back Bay. Fish were transferred back to Hooper's in March 1998 following problems with tail attrition.

Larvae from the 1998 hatch were of Saint John origin. These were retained until early October, when they were sold to Aqua Malobiannah of Pohénégamook, Quebec.

Aqua Malobiannah, Pohénégamook, Quebec

This is a private firm whose main business is salmonid aquaculture. Its facilities are located in the drainage basin of the Saint John River, near the borders of both Maine and New Brunswick. In fall 1998, the company obtained young-of-the-year striped bass of Saint John origin from Hooper's Hatchery. These were placed in land-based tanks for further growth. The firm anticipates expansion of its striped bass program through further fish acquisitions.

Maritime Culture Systems, St. Martins NB

This commercial striped bass facility was operated from 1991 to 1996 at St. Martins, on the Fundy coast of New Brunswick (Fig. 1). The objective was to raise striped bass to market size for human consumption, and also for sale as fingerlings to grow-out operators in the US. The facility consisted of indoor tanks and large outdoor ponds, artificially excavated, with plastic liners. The water supply was both flow-through and recirculated. All water was pumped from a well. All effluent went into a settling pond, then to a dispersion field where it percolated into a nearby stream. Due to this method of water handling, the operators considered that no bass could have escaped from the facility.

In 1991 and 1992, the facility infrastructure was developed. Broodstock from the Miramichi and Stewiacke/Shubenacadie were collected and maintained, but not spawned. Miramichi bass were collected from the bycatch of gaspereau traps, and Stewiacke/Shubenacadie broodstock were obtained from the SABS. In subsequent years, additional broodstock were reared from larvae.

The first spawning took place in spring 1993, using two females from the Stewiacke/Shubenacadie and four from the Miramichi. In addition, fertilized eggs from a single female spawned at the Miramichi Hatchery were brought to St. Martins (see below). Mortality of juvenile fish was high due to predation by giant water bugs. About 3,000 survived to the fingerling stage. Of these, 2,500 were shipped to a commercial bass grow-out operation in Massachusetts. The other 500 were overwintered in indoor tanks.

In 1994, 10 females, of Miramichi and Stewiacke/Shubenacadie origin, were spawned. Larvae were put in ponds, where the major mortality was due to great blue herons. About 5,000-6,000 survived to the fingerling stage.

In fall 1994, the 1993 hatch year had reached weights of 1.25 - 1.5 lbs (570-680 g), and were sold to a fish market in Toronto.

In 1995, broodstock were again spawned, and about 3000 fry and 100 juveniles (20 mm total length) of Miramichi parentage were shipped to SUNY.

In 1995, the site's water permit was reduced from 50 to 7 gallons per minute due to lack of water in wells in the area. In addition, fingerlings had to be destroyed because of a 2-day power failure. Because the facility was not commercially viable at the lower level of water supply, the operation ended in spring 1996. At that time the broodstock was again spawned, and progeny was sent (about 5000 Miramichi origin, about 5000 Stewiacke/Shubenacadie origin) to SUNY. The Miramichi broodstock were transferred to the Cardigan Fish Hatchery. Some of the Stewiacke/Shubenacadie broodstock were sent to SABS, and some were filleted and eaten.

Nova Scotia Agricultural College, Truro NS

The Nova Scotia Agricultural College's (NSAC's) aquaculture facilities include indoor tanks with recirculating water systems. In 1997 eggs of Stewiacke/Shubenacadie origin were obtained from the Two Rivers Bass Hatchery, and the ensuing juveniles were maintained for 9 months, when they reached 140 g. In 1998, eggs and larvae were obtained from southwestern New Brunswick (Huntsman, Hooper's Hatchery) because problems with water conditions at Two Rivers impaired survival. These eggs are of presumed Stewiacke/Shubenacadie origin. Research on these fish focused on fatty acid requirements and feeding and gut evacuation of larvae, and the effect of swimming speed on growth rate of juveniles.

Two Rivers Bass Hatchery, Stewiacke NS

The Two Rivers Bass Hatchery is a privately operated facility at the confluence of the Stewiacke and Shubenacadie Rivers on the Bay of Fundy watershed of Nova Scotia (Fig. 1). The facility consists of indoor tanks and outdoor earthen ponds, into which river water is pumped. Faculty (Jim Duston) and students of NSAC have worked with the Two Rivers Bass Hatchery in ovulation induction and in various research projects. The Stewiacke/ Shubenacadie system is the origin of all striped bass used at the hatchery.

Operations began about 1991, when eggs captured by plancton net were hatched and raised on a small scale. Culture continued by this method until about 1996, when broodstock taken as bycatch of the drift gillnet fishery for shad in the lower Shubenacadie were used as a source of eggs. This method was also used in 1997 and 1998. Spawning takes place in the indoor tanks, and the progeny are later transferred to the earthen ponds. These ponds are used to overwinter both juvenile and adult (broodstock) fish. Fish in ponds receive artificial foods, although they can also grow well on the natural food in the ponds. Culture of progeny was relatively successful in 1996 and 1997, but less so in 1998 because of excessive temperatures at spawning time. Fish are marketed at age 30 months.

In addition to striped bass retained for grow-out to market size, the facility has provided young of the year to the SABS, Aquafutures in Massachusetts, and Aqua Health Ltd. of Charlottetown PEI.

Halifax DFO lab

The Annapolis River is a traditional striped bass spawning site, but striped bass larvae in the river suffer high or total mortality due to poor water quality (Jessop 1990). Eggs from the Annapolis are viable and have a high hatching rate when incubated in water of suitable quality (Jessop 1990). This suggests that a program in which progeny are removed from the Annapolis during the sensitive larval phase might be an effective means of stock enhancement. Consequently, in spring 1981, striped bass eggs were collected from the Annapolis River and hatched at DFO's Water Street lab in Halifax. Larvae were reared with minimal mortality and nearly 600 fingerlings (sizes 60-80 mm) were released back into the river in September 1981 (Jessop 1995). Released fish were fitted with coded wire tags. The survival of these released fish was not monitored and the enhancement program was not continued.

Loch Bras d'Or Salmon Farms, Whycocomagh NS

This is a privately operated facility which raises salmonids in sea cages in an arm of the Bras d'Or Lakes, Cape Breton Island. In March 1994, the firm received about 100 0+ striped bass of Stewiacke/Shubenacadie origin from SABS. These fish, which had been previously reared in heated salt water, were placed in tanks supplied with cold fresh water pumped from the lake surface. The fish did not feed and subsequently died.

Cardigan Fish Hatchery, PEI

The fish hatchery at Cardigan in eastern PEI was operated by the Department of Fisheries and Oceans until October 1997, when it was divested to the University of Prince Edward Island, whose subsidiary, AVC Inc., is the facility operator. Striped bass have been spawned at this facility both before and after the divestiture.

Striped bass culture work began in June 1992, when nine bass were captured in gaspereau gear at the head of the Hillsborough River and were transferred to Cardigan. These fish were not spawned, but were held for spawning in subsequent years.

In June 1993, the Hillsborough bass were spawned and the progeny were taken to the yolk sac absorption stage, when the experiment was terminated.

In June 1994, the Hillsborough fish were again spawned, and the progeny raised to first feeding. Most of the young were destroyed, but a small group (about 200) was kept until 1997 when they were sacrificed for disease analysis by the Atlantic Veterinary College (no disease was found).

In June 1995, the Hillsborough bass were spawned. About 1000 fry were sent to SUNY. Several thousand others were sent to SABS for growth trials; some of these fish were subsequently sent to Aquafutures in Massachusetts. The remainder were kept to age two months when they were destroyed. On 2 July 1995, a striped bass captured in a research salmon trap in the Morell River was transported to Cardigan to join the Hillsborough fish.

In June 1996, the Hillsborough/Morell bass were spawned. Shortly after, all broodstock except one Hillsborough fish died due to the mis-placement of a standpipe in their tank. The fry from this spawning died several days later due to accidental electrocution.

In October 1996, new broodstock of Miramichi origin were obtained (from Maritime Culture Systems, St. Martins). These fish, plus the surviving Hillsborough fish, were spawned in June 1997. The young were taken to the fry stage but were lost, apparently due to a problem with screening. These fry were presumably carried into the Cardigan River, which receives outflowing water from the Cardigan Hatchery.

In June 1998, the Miramichi/Hillsborough bass were spawned and the young were brought to the age of first feeding, when they were destroyed.

Tracadie Bay, PEI

In 1991 and 1992, a commercial striped bass aquaculture venture was initiated in Tracadie Bay, PEI. In both years, attempts were made to procure striped bass from the eel fyke-net fishery at the head of the Hillsborough River (Fig. 1). However, bass which were caught were in poor condition due to confinement in the small eel nets, and did not survive. The major winter smelt fishermen on PEI were canvassed in search of sources of striped bass, but all of the fishermen who were interviewed reported that they had never caught a striped bass in smelt gear in winter.

In June 1992, 200 bass captured in the gaspereau fishery of the Richibucto River, NB, were brought to PEI, but only five survived to 6 July 1992. The high mortality was attributed to rough handling and ensuing scale loss. On 3 July, 220 more bass were transported from the Miramichi River to PEI. These were treated more carefully, and the fish arrived on PEI in good condition. Of this second batch, 150 fish were 4-6 inches (10.2-15.2 cm) and 70 were 9-12 inches (22.9-30.5 cm) long. On the basis of length distributions recorded on the Miramichi River (Bradford et al. 1995), these fish would be age 1+ and 2+, respectively.

The striped bass were quarantined for about 6 weeks in tanks with a recirculating water system at Pleasant Grove, near the Winter River, a tributary of Tracadie Bay. The water supply was fresh water to which Instant Ocean was added. Effluent was treated. The fish were then transferred to tanks with a marine flow-through water supply. Subsequently, they were placed in sea cages in Winter Bay, an arm of Tracadie Bay, where they were fed shelled mussels and moist salmon food. In fall 1992 the cages were cut by vandals and the fish escaped.

Aqua Health Ltd., Charlottetown PEI

Aqua Health is a federally-certified developer and producer of fish vaccines. Fish are kept in land-based tanks with recirculated water; all effluent is treated. In 1996, Aqua Health brought in young-of-the-year striped bass from Two Rivers Bass Hatchery, but there were problems in maintaining water conditions during transport and the fish died. Subsequently, striped bass were obtained from Aquafutures in Massachusetts. These fish were successfully maintained, and were used in preliminary development work for a vaccine against *Streptococcus iniae*, a pathogen which affects striped bass and which may also affect immunosuppressed humans. Following the conclusion of this work, the fish were destroyed and their remains autoclaved before disposal.

Ellerslie Aquaculture Station, Ellerslie PEI

This is the site of Holland College's aquaculture instruction program. About 1994, about 10 striped bass were taken from a fall trap fishery (eels or smelts) in the Bideford River, which is adjacent to the station. These fish were held in land-based tanks for about two years, when they were destroyed. Bass were about 30 cm long when captured, and about 50 cm long at the end of the project.

Miramichi Hatchery

The Miramichi Fish Hatchery was operated by the Department of Fisheries and Oceans until October 1997, when it was divested to the Miramichi Watershed Management Committee. All broodstock used in striped bass work was obtained from commercial gaspereau traps and from traps authorized under an aboriginal fisheries agreement. Both types of traps were located within 1.5 km of the Miramichi Hatchery, and all broodstock taken into captivity were released shortly after spawning.

Striped bass spawning was first initiated in 1993, with a single female. Fertilized eggs were transferred to Maritime Culture Systems in St. Martins NB, where they were hatched and the progeny raised.

There were no striped bass spawnings in 1994. In 1995, two female bass were spawned. The percent survival of eggs was low, and larvae did not live past summer.

In 1996, several striped bass were spawned. Survivorship was low, but some fish survived until September when they were released into the Miramichi system. In October, 12 fish were obtained from Maritime Culture Systems, St. Martins; these were the product of the spawning at the Miramichi Hatchery in 1993. Due to cool water temperatures these fish stopped feeding and became emaciated, and were destroyed by December.

In 1997, several striped bass were spawned. There were problems in inducing the juvenile fish to feed. All either died or were liberated by August.

In 1998, four females were captured for spawning purposes, but due to low water temperatures spawning was delayed and offspring were not viable.

Shippagan Marine Centre, NB

The Shippagan Aquarium and Marine Centre (Centre marin de Shippagan) is a marine tourism, education and research centre in northeastern New Brunswick (Fig. 1). It is operated by the New Brunswick Department of Fisheries and Aquaculture.

Striped bass have been held at the Centre since 1994. Fifty striped bass, held in public display tanks, are F1 progeny of Miramichi lineage. These were obtained in

1997 when SABS closed its striped bass program. Twenty-two striped bass, taken from the Napan River (a tributary of Miramichi Bay) are in non-display tanks. No spawnings have been attempted at the Shippagan Centre.

Aquaculture Matane Inc., Matane, Quebec

This venture was initiated at Matane on the south shore of the lower St. Lawrence estuary about 1994, with the help of a large federal grant. Twenty striped bass under 18" (46 cm) were brought in from the Miramichi. These fish failed to show adequate growth due the cold temperature of the water, which was obtained from the St. Lawrence River. After a year the enterprise became bankrupt and the fish were destroyed.

Quebec Aquarium

This is a major display centre for fish and other aquatic life in Quebec City. The Aquarium acquired eight striped bass from SABS (Miramichi origin) in October 1997. One fish had to be destroyed due to skin ulcerations, and seven striped bass (length range 40-45 cm) are currently held at the Aquarium.

Montreal Biodome

The Montreal Biodome is a large exhibition centre for natural life, and also has a mandate to support conservation. Since 1992, the Biodome has held for public display 20 striped bass which originated from coastal Maine. It also holds 70 striped bass which were obtained from the Shippagan Marine Centre in November 1997, which had obtained them from SABS in September 1997. These fish were the F1 progeny of parents captured on the Kouchibouguac River, NB. They are kept in isolation, and are reserved for future research and conservation programs.

Potential striped bass culture operations

Hamilton's Eel Fishery of Granville Ferry, Annapolis County NS, is planning to begin striped bass culture in 1999.

AVC Inc., of which the Cardigan Fish Hatchery is an operating unit, is a subsidiary of the University of PEI and has close links with the Atlantic Veterinary College. AVC Inc. has a strong interest in developing and testing striped bass aquaculture methodology.

The Université du Québec à Rimouski (UQAR) is located on the lower St. Lawrence Estuary, and its affiliated marine station at Grande Rivière is located on the Gulf of St. Lawrence coast of the Gaspé Peninsula. Nathalie LeFrançois of UQAR has in interest in developing striped bass culture for the purpose of re-establishing a wild stock in the St. Lawrence River, from which striped bass are presently extirpated.

DISCUSSION

The striped bass industry in eastern Canada

Striped bass culture in eastern Canada began with a pilot enhancement program in the Annapolis River in 1981, and experimental rearing work at St. Andrews Biological Station in the late 1980s. In the ensuing decade, numerous faltering steps have been made, but the industry remains firmly in its infancy. Of the eight commercial ventures begun in the region, only four are still operating, and only two of these have made commercial sales (Hooper's Hatchery, Two Rivers) (Table 1). There have also been reversals in the research/development arena, and several research facilities (notably the St. Andrews Biological Station) are no longer culturing striped bass.

The failure of striped bass culture to blossom into a full fledged industry has not been due to insurmountable technical difficulties. Problems have ranged from bird predation to excessive water temperatures, but the difficulties encountered are generic to finfish aquaculture and are solvable with appropriate techniques, equipment, and sites. Likewise, the slow development of striped bass culture is not due to lack of seedstock. Because of their high fecundity, a small number of spawning females can produce a large quantity of eggs. Most aquaculturists who wanted adult or young striped bass appear to have been able to procure them.

Instead, the slow development of Canada's striped bass industry appears to be due to the fact that major capital investment, appropriate choice of site and equipment, and expert husbandry have not yet come together at the same place and time. A potential Canadian striped bass industry may have the advantage of access to seedstock with an intrinsically high growth rate (Conover et al. 1997), but it also faces the disadvantage of a short season in which natural water temperatures are sufficiently high to promote growth. Evaluation of the economic viability of large-scale striped bass aquaculture in eastern Canada would require detailed analysis that is beyond the scope of this paper.

Information needs

Most of the site accounts in this paper are based on the recollections of facility operators, in some cases supplemented by reference to written records. It is therefore not surprising that there were inconsistencies between reports of providing and receiving parties regarding the dates and stock origins of fish transfers.

Reliable information on fish transfers is needed for the following reasons:

a) Stock origin of fish has an influence on innate growth rates (Conover et al. 1997). Therefore reliable information on genetic origin is needed for the development of strains with optimum culture performance.

b) If fish escape from culture, information on the genetic origin of escapees is needed to evaluate the potential genetic effects on local wild stocks (Bradford and Hutchings 1999).

c) If disease appears in culture facilities or wild stocks, reliable information on transfers is needed to determine whether pathogens could have arrived with the transfers.

Two reports were received of escapes of striped bass under culture. Given the anecdotal nature of the information source, other escapes may have occurred that are not reported here. Timely and reliable information on escapes is needed for the following reasons:

a) To evaluate the potential effects on wild stocks in the event that escapees interbreed with wild fish,

b) To evaluate the potential role of escapees in carrying disease to wild stocks and to other aquaculture operations, and

c) To permit immediate response (containment or re-capture of escapees) where this is feasible and deemed necessary.

RECOMMENDATIONS

It is recommended that a data-gathering system be put in place that systematically records all transfers of striped bass genetic material, including milt, eggs, larvae, juveniles, and adults, within eastern Canada and between eastern Canada and other areas. The system should record the dates, numbers, life stages, health status, providing facilities, genetic origins, and destinations of transfers. Movements between culture and the wild state in either direction (including escapes) would be considered transfers and would be recorded by the system.

This system should record data in permanent archives, in a manner analogous to fishery landing statistics. The system should have clear rules regarding confidentiality and public disclosure of data. Confidentiality of private operations should be respected where appropriate, but in cases where the interest of private confidentiality conflicts with a broader public interest for information release (safeguarding of wild stocks, welfare of fish held in other aquaculture facilities), then the public interest should prevail.

In the event of an escape, facility operators should be obliged to inform regulatory authorities immediately, so that remedial or containment actions can be taken without delay.

It is beyond the scope of this paper to lay out in detail how a recording and reporting system for striped bass transfers might be administered. Both federal and provincial governments have an interest in wild fish and in aquaculture. If the data recording system is operated by more than one government, then data gathering and archiving should be set up under common protocols so that inter-provincial transfers, and releases or escapes of fish that might later cross provincial boundaries, can be readily traced.

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LITERATURE CITED

Bradford, R.G., D.K. Cairns, and B. Jessop. 1999a. Update on the status of striped bass (*Morone saxatilis*) in eastern Canada in 1998. Department of Fisheries and Oceans Canadian Stock Assessment Secretariat Res. Doc. 99/01.

Bradford, R.G., G. Chaput, S. Douglas, and J. Hayward. 1999b. Status of striped bass (*Morone saxatilis*) in the Gulf of St. Lawrence in 1998. Department of Fisheries and Oceans Canadian Stock Assessment Secretariat Res. Doc. 99/02.

Bradford, R.G. and J. Hutchings. 1999. Genetic interaction between artificially-reared and wild Canadian striped bass (*Morone saxatilis*): risk and uncertainties. Department of Fisheries and Oceans Canadian Stock Assessment Secretariat Res. Doc. 99/03.

Bradford, R.G., K.A. Robichaud, and S.C. Courtenay. 1995. By-catch in commercial fisheries as an indicator and regulator of striped bass (*Morone saxatilis*) abundance in the Miramichi River estuary. Can. Spec. Publ. Fish. Aquat. Sci. 123:249-259.

Brown, J.J., A. Ehtisham, and D.O. Conover. 1998. Variation in larval growth rate among striped bass stocks from different latitudes. Trans. Am. Fish. Soc. 127:598-610.

Conover, D.O., J.J. Brown, and A. Ehtisham. 1997. Countergradient variation in growth of young striped bass (*Morone saxatilis*) from different latitudes. Can. J. Fish. Aquat. Sci. 54:2401-2409.

Harrell, R. 1999. Overview of striped bass aquaculture breeding programs and review of studies conducted on the interaction between aquaculture escapees and wild striped bass in the United States. Department of Fisheries and Oceans Canadian Stock Assessment Secretariat Res. Doc. 99/05.

Jessop, B.M. 1990. The status of striped bass in Scotia-Fundy Region. Can. Atl. Fish. Sci. Adv. Comm. Res. Doc. 90/36.

Jessop, B.M. 1995. Update on striped bass stock status in Scotia-Fundy Region and proposals for stock management. DFO Atl. Fish. Res. Doc. 95/8.

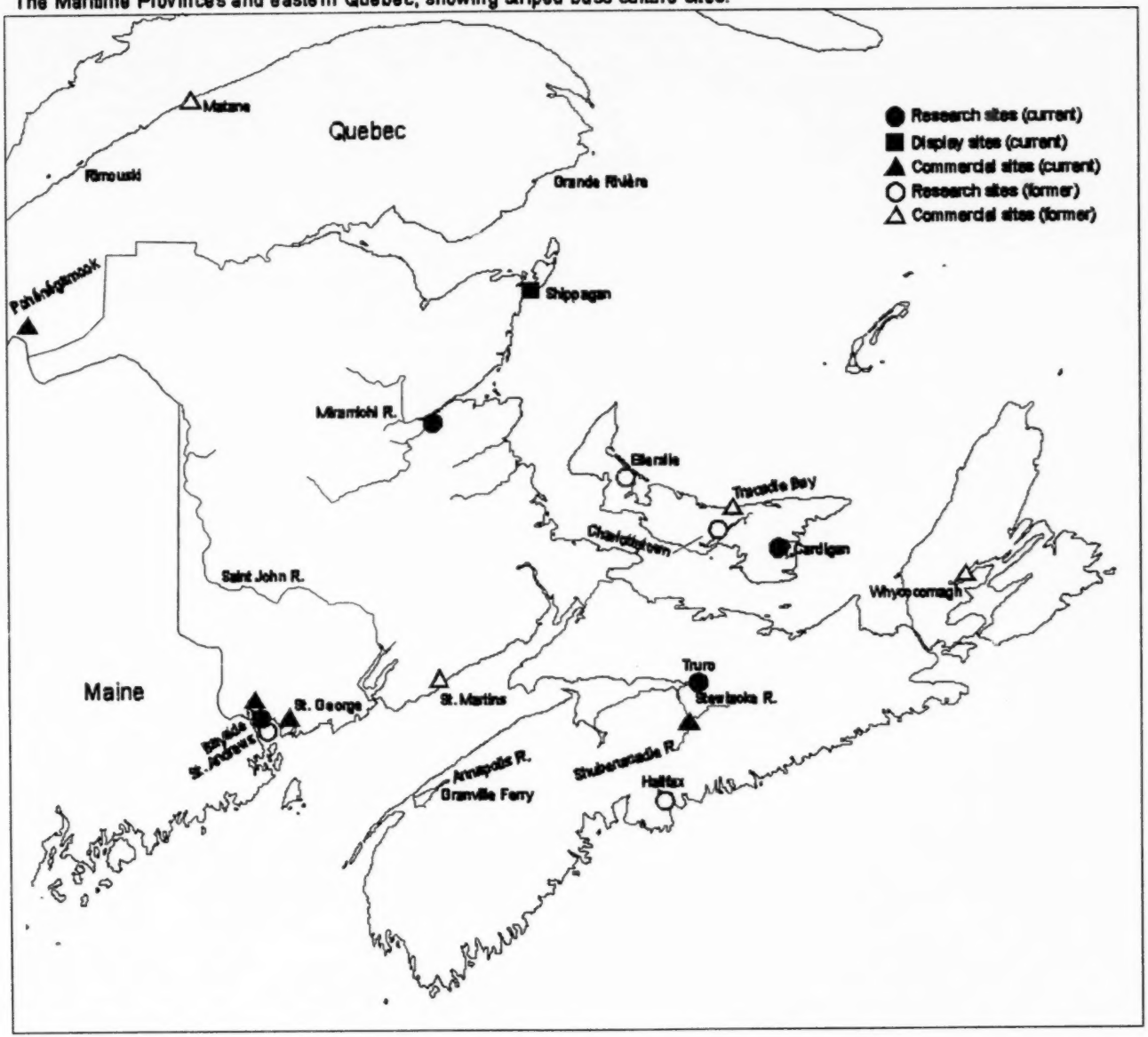
Peterson, R.H., D.J. Martin-Robichaud, P. Harmon and A. Berge. 1996. Notes on striped bass culture, with reference to the Maritime Provinces. Department of Fisheries and Oceans, Halifax.

Table 1
A classification of striped bass culture operations in eastern Canada.

Purpose	Currently working with striped bass	Number	Facilities
Research*	Yes	4	Huntsman, NSAC, Cardigan, Miramichi
Research*	No	4	SABS, Halifax Lab, Aqua Health Ltd., Ellerslie
Display**	Yes	3	Shippagan, Quebec Aquarium, Montreal Biodome
Display**	No	0	
Commercial	Yes	4	Woodstock Cold Storage, Hooper's Hatchery, Aqua Malobiannah, Two Rivers
Commercial	No	4	Maritime Culture Systems, Loch Bras d'Or, Tracadie Bay PEI, Aquaculture Matane
Total		19	

*May also include development and training
**May also include development, training, and enhancement/restoration

Fig. 1
The Maritime Provinces and eastern Quebec, showing striped bass culture sites.



Appendix 1.
List of contact names and addresses of striped bass culture facilities in eastern Canada. Other persons who have supplied information used this paper are also listed.

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